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**APPLICATION
FOR
UNITED STATES
LETTERS PATENT**

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FOR: SEMICONDUCTOR DEVICE AND
METHOD FOR FABRICATING SAME

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SEMICONDUCTOR DEVICE AND METHOD FOR FABRICATING SAME

FIELD OF THE INVENTION

The invention relates to a semiconductor device and a
5 method for fabricating the same, and especially to a
semiconductor device in which a semiconductor chip is assembled
into a printed circuit board and a method for fabricating the
same.

BACKGROUND OF THE INVENTION

10 In recent years, an electronic device has come to be
integrated with high density, and a semiconductor chip with
multiple terminals is packaged in accordance with an
improvement of the function and thinning of an electronic
15 circuit. Accordingly, a package of the semiconductor chip used
in the electronic circuit is miniaturized and provided with
multiple pins. In conformity with the aforementioned tendency,
the semiconductor chip is assembled into a printed circuit board
by means of a package of an area array type, such as a ball grid
20 array package (BGA), a chip scale package (CSP) or a bare chip
package (a flip chip package, FC).

FIG.1 shows a typical example of the structure of the
aforementioned packages of the semiconductor chips. In the
package shown in FIG.1, a chip-mounting substrate 103 on which
25 a semiconductor chip 100 has been mounted by means of wire-
bonding is assembled into a printed circuit board 104 by CSP,
where the chip-mounting substrate 103 is composed of an
insulating substrate 101 formed of ceramics, polyimide, etc.

and conductor wirings 102.

In the package having the aforementioned structure, a clearance formed between the chip-mounting substrate 103 and the printed circuit board 104 is filled with underfill material 105 in order to absorb a stress caused by a difference in the thermal expansion coefficient between the chip-mounting substrate 103 and the printed circuit board 104 and impacts caused by fallings to secure the reliability of soldered jointed portions.

However, if alien substances mix with underfill material 105 or the impacts exert on under fill material 105 for a long period of time, an adhesive strength of underfill material 105 is lowered, and underfill material 105 may exfoliate from the surface of the chip-mounting substrate 103 or of the printed circuit board 104.

If underfill material 105 exfoliates from the chip-mounting substrate 103 or the printed circuit board 104, since the stress concentrates on jointed portions of the solder balls 106, cracks occur on pads 107, 108 which are respectively formed on surfaces of the chip-mounting substrate 103 and the printed circuit board 104, and the jointed portions become disincentive. As mentioned in the above, the reliability of the semiconductor device is lowered because of lowering of the adhesive strength of underfill material 105.

In Japanese Patent Applications, Laid-Open, No.63-94646, an electronic device in which unevennesses are respectively provided for a predetermined part of a chip-mounting substrate and sealing resin for sealing a semiconductor chip is disclosed

as a means for increasing an adhesive strength between the chip-mounting substrate and the basic substrate. That is to say, in the aforementioned semiconductor device, concave portions and convex portions are alternately formed on the chip-mounting substrate and on sealing resin for covering the semiconductor chip, and the chip-mounting substrate on which the semiconductor chip is mounted is buried in a cavity formed in the basic substrate. Accordingly, the aforementioned technology cannot be applied to a package of an area array type.

Although a semiconductor device in which a bonding wire is prevented from being disincement by providing unevenness for a pad is disclosed in Japanese Patent No.2973988, underfill material is not prevented from being exfoliated according to this technology.

In a semiconductor device in which a semiconductor chip mounted on a lead frame is assembled into a printed circuit board, since there is a difference in a thermal expansion coefficient between the lead frame and a pad of the printed circuit board, the lead frame may exfoliate from the printed circuit board at a contact surface therebetween because of an impact caused by a thermal shock.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the invention to provide a semiconductor device in which a chip-mounting substrate or a lead frame adheres to a printed circuit board tightly, and a method for fabricating the same.

It is a further object of the invention to provide a semiconductor device operating in an electronic circuit with high reliability, and a method for fabricating the same.

A semiconductor device concerned with the first viewpoint
5 of the invention comprises:

a semiconductor chip,

a chip-mounting substrate which is provided with the semiconductor chip mounted on a top surface thereof and the first conductive pads formed on a bottom surface thereof and
10 connected with the semiconductor chip electrically,

solder balls formed on the first conductive pads,

a printed circuit board on which second conductive pads connected with the solder balls are formed, and

underfill material injected into a clearance formed
15 between the chip-mounting substrate and the printed circuit board,

wherein unevenness is formed on a surface which is brought into contact with the underfill material of at least one of the chip-mounting substrate and the printed circuit board.

20 According to the aforementioned structure, since an area of a contact surface between the chip-mounting substrate and underfill material increases, an adhesive strength between the chip-mounting substrate and underfill material is heightened. Accordingly, the chip-mounting substrate becomes hard to
25 exfoliate from underfill material, and an adhesive strength between the chip-mounting substrate and the printed circuit board is heightened. Moreover, since the adhesive strength between the chip-mounting substrate and the printed circuit

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board is heightened, a disconnection between the solder ball and the pad becomes hard to occur. Accordingly, the semiconductor device operating in the electronic circuit with high reliability can be obtained.

5 The aforementioned unevenness may be selectively formed on the first conductive pads or on the second conductive pads.

Moreover, the aforementioned unevenness may be shaped into a slit-like configuration or into a dimple-like configuration.

10 A semiconductor device concerned with the second view point of the invention comprises:

a semiconductor chip,

15 a lead frame which is provided with the semiconductor chip mounted thereon and electrically connected with the semiconductor chip, and

a printed circuit board including the third conductive pads which are formed thereon and brought into contact with the lead frame,

20 wherein at least one of the lead frame and the printed circuit board is provided with unevennesses at contact surfaces therebetween.

25 According to the aforementioned structure, since an area of a contact surface between the lead frame and the printed circuit board increases, the lead frame becomes hard to exfoliate from the printed circuit board, and the adhesive strength between the lead frame and the printed circuit board is heightened. Moreover, since the adhesive strength between the lead frame and the printed circuit board is heightened, a

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jointed portion between the lead frame and the printed circuit board becomes hard to be disincentive. Accordingly, the semiconductor device operating in the electronic circuit with high reliability can be obtained.

5 A method for fabricating a semiconductor device concerned with the third viewpoint of the invention comprises the steps of:

 forming the fourth conductive pads on a bottom surface of a chip-mounting substrate,

10 forming unevenness on the bottom surface of the chip-mounting substrate,

 mounting a semiconductor chip on a top surface of the chip-mounting substrate,

15 connecting the semiconductor chip with the fourth conductive pads electrically,

 forming solder balls on the fourth conductive pads,

 assembling the chip-mounting substrate into a printed circuit board by connecting solder balls with the fifth conductive pads formed on the printed circuit board, and

20 injecting underfill material into a clearance formed between the chip-mounting substrate and the printed circuit board.

 According to the aforementioned structure, since an area of a contact surface between the chip-mounting substrate and underfill material increases, the adhesive strength between the
25 chip-mounting substrate and underfill material is heightened. Accordingly, the chip-mounting substrate becomes hard to exfoliate from underfill material, and the adhesive strength

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the steps of:

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chip-mounting substrate,

conductive pads electrically,

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board.

According to the aforementioned structure, since an area of the contact surface between the printed circuit board and underfill material increases, the adhesive strength between the printed circuit board and underfill material is heightened.

5 Accordingly, underfill material becomes hard to exfoliate from the printed circuit board, and the adhesive strength between the chip-mounting substrate and the printed circuit board is heightened. Moreover, since the adhesive strength between the chip-mounting substrate and the printed circuit board is
10 heightened, a disconnection between the solder ball and the pad becomes hard to occur. Accordingly, the semiconductor device operating in the electronic circuit with high reliability can be obtained.

The step of forming unevenness on the surface of the
15 printed circuit board may comprise the step of forming unevennesses on the surfaces of the seventh conductive pads selectively.

A method for fabrication a semiconductor device concerned with the fifth view point of the invention comprises the steps
20 of:

forming the eighth conductive pads on a bottom surface of a chip-mounting substrate,

forming the first unevenness on a bottom surface of the chip-mounting substrate,

25 mounting a semiconductor chip on a top surface of the chip-mounting substrate,

connecting the semiconductor chip with the eighth conductive pads electrically,

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The step of forming unevenness on the bottom surface of the chip-mounting substrate may comprise the step of forming unevennesses on the surfaces of the eighth conductive pads

selectively, and

The step of forming unevenness on the top surface of the printed circuit board may comprise the step of forming unevennesses on the surfaces of the ninth conductive pads
5 selectively.

A method for fabricating a semiconductor device concerning with the sixth view point of the invention comprises the steps of:

forming unevennesses on predetermined parts of a lead
10 frame,

mounting a semiconductor chip on the lead frame,

connecting the semiconductor chip with the lead frame electrically, and

assembling the lead frame on which the semiconductor chip
15 is mounted into a printed circuit board by bringing the unevennesses formed on the lead frame into contact with tenth conductive pads formed on the printed circuit board.

According to the aforementioned structure, since areas of the contact surfaces between the lead frame and the printed
20 circuit board increase, the lead frame becomes hard to exfoliate from the printed circuit board, and the adhesive strength between the lead frame and the printed circuit board is heightened. Moreover, since the adhesive strength between the lead frame and the printed circuit board is heightened, a
25 disconnection of a jointed portion between the lead frame and the printed circuit board becomes hard to occur. Accordingly, the semiconductor device operating with high reliability in the electronic circuit can be obtained.

A method for fabricating a semiconductor device concerned with the seventh view point of the invention comprises the steps of:

mounting a semiconductor chip on a lead frame,

5 forming unevennesses on surfaces of eleventh conductive pads formed on a printed circuit board, and

assembling the lead frame on which the semiconductor chip is mounted into the printed circuit board by connecting the lead frame with the eleventh conductive pads on which the unevennesses are formed.

A method for fabricating a semiconductor device concerned with the eighth viewpoint of the invention comprises the steps of:

forming the first unevennesses on predetermined parts of a lead frame,

mounting a semiconductor chip on the lead frame,

connecting the semiconductor chip with the lead frame electrically,

forming the second unevennesses on surfaces of twelfth conductive pads formed on a printed circuit board, and

assembling the lead frame on which the semiconductor chip is mounted into the printed circuit board by bringing the first unevennesses formed on the lead frame into contact with the second unevennesses formed on the twelfth conductive pads.

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BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be explained in more detail in

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conjunction with appended drawings, wherein:

FIG.1 is a cross-sectional view for showing a conventional semiconductor device,

FIGs. 2A to 2D are cross-sectional vies for showing a
5 semiconductor device according to the first preferred embodiment of the inveniton,

FIGs. 3A, 3B are cross-sectional view for showing modifications of a semiconductor device according to the first preferred embodiment of the invention,

10 FIGs.4A, 4B are cross-sectional view for showing modifications of a semiconductor device according to the first preferred embodiment of the invention,

FIGs.5A to 5D are cross-sectional views for showing a semiconductor device according to the second preferred
15 embodiment of the invention,

FIGs. 6A, 6B are cross-sectional views for showing modifications of a semiconductor device according to the second preferred embodiment of the invention,

FIG.7A is a plan view of showing a lead frame used in a
20 semiconductor device according to the third preferred embodiment of the invention,

FIG.7B is a cross-sectional view for showing a lead frame used n a semiconductor device according to the third preferred embodiment of the invention,

25 FIG.8 is a plan view for showing a semiconductor device according to the third preferred embodiment of the invention, and

FIGs. 9A, 9B are cross-sectional views for showing a

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semiconductor device according to the third preferred embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

5 Hereafter, preferred embodiments of the invention will be explained.

[The First Preferred Embodiment]

As shown in FIG.2D, a semiconductor device according to the first preferred embodiment is fabricated by packaging a semiconductor chip in accordance with CSP (chip scale package), and provided with a chip-mounting substrate 10, semiconductor chip 20, and a printed circuit board 30.

10 The chip-mounting substrate 10 is composed of a glass fiber-reinforced epoxy substrate (a glass epoxy substrate, hereinafter) 11 of a single layer which is provided with plural through holes 12 formed on a periphery thereof, lands 13 formed on a top surface of the glass epoxy substrate 11, Cu wirings (pads) 14 which are formed on a bottom surface of the glass epoxy substrate 11 and connected with the lands 13 via the through holes 12, and solder balls 24 formed on the Cu wirings 14. A solder mask 15 is formed on the Cu wirings 14 and the lands 13. Moreover, unevenness is provided for a bottom surface of the solder mask 15 which is framed on the Cu wirings 14.

20 A semiconductor chip 20 adheres to a central area of the chip-mounting substrate 10 by means of die bonding material 16, and pads (not shown) formed on the semiconductor chip 20 are connected with the lands 13 by Au wires (bonding wires) 21. Moreover, the semiconductor chip 20, the Au wires 21, and the

lands 13 are sealed with sealing resin 22.

A printed circuit board 30 which is opposite the chip-mounting substrate 10 is provided with pads 31, which are respectively connected with the solder balls 24.

5 A clearance formed between the chip-mounting substrate 10 and the printed circuit board 30 is filled with underfill material 32.

Hereafter, a method for fabricating the semiconductor device will be explained.

10 As shown in FIG.2A, the through holes 12 are formed on the periphery of the glass epoxy substrate 11 by means of photolithography and laser beam irradiation. Next, a Cu layer is formed on the surfaces of the glass epoxy substrate 11 including the inner surfaces of the throughout holes 12.

15 Subsequently, the Cu layer is etched to form the lands 13 on the top surface of the glass epoxy substrate 11 and to form the Cu wirings 14 on the bottom surface of the glass epoxy substrate 11. After the lands 13 and the Cu wirings 14 are formed, the solder mask 15 is formed on both the surfaces of the glass epoxy

20 substrate 11 including the inner surfaces of the through holes 12. After the solder mask 15 is formed, the solder mask 15 just above the lands 13 are etched and removed, and the semiconductor chip 20 adheres to the central area of the glass epoxy substrate 11 by means of die boding material 16. Subsequently, the pads

25 formed on the semiconductor chip 20 are respectively connected with the lands 13 by the Au wires 21. Thereafter, the semiconductor chip 20, the Au wires 21, and the lands 13 are sealed with sealing resin 22.

Next, as shown in FIG.2B, the solder mask 15 formed on the Cu wirings 14 is grinded mechanically by using a buff brush, and made rough. Thereby unevenness is formed on the bottom surface of the chip-mounting substrate 10. Thereafter, the surface of the chip-mounting substrate 10 is washed by cleansing liquid.

Next, in order to form the solder balls 24 on the Cu wirings 14, the solder mask 15 is etched to form contact holes 23 communicating with the Cu wirings 14 as shown in FIG.2C. Subsequently, the solder balls 24 are formed on the Cu wirings 14 by thermal compression welding.

Next, as shown in FIG.2D, the chip-mounting substrate 10 is so positioned opposite to the printed circuit board 30 that the solder balls 24 on the chip-mounting substrate 10 are respectively aligned with the corresponding pads 31 on the printed circuit board 30. Then, they are brought into contact with each other, a reflow process is conducted, and the solder balls 24 are connected with the pads 31 on the printed circuit board 30.

Finally, underfill material 32 is injected into a clearance formed between the chip-mounting substrate 10 and the printed circuit board 30, and hardened.

As mentioned in the above, since an area of a contact surface between the chip-mounting substrate 10 and underfill material 32 is increased by providing unevenness for the bottom surface of the chip-mounting substrate 10, an adhesive strength between the chip-mounting substrate 10 and underfill material 32 is heightened. Accordingly, underfill material 32 is

prevented from being exfoliated from the chip-mounting substrate 10 because of impacts caused by fallings, bendings or thermal shocks. As a result, the semiconductor device operating in the electric circuit with high reliability can be obtained.

5 Although the glass epoxy substrate 11 is used as material of the chip-mounting substrate 10 in the aforementioned embodiment, a plastic substrate, a polyimide tape substrate, or a ceramic substrate can be adopted for the same purpose. Moreover, although Cu is used as material of the wiring and the land, and the Au wire is used as the bonding wire in the
10 aforementioned embodiment, the other materials may be adopted for the same purpose.

 Although the solder mask 15 is formed on both the surfaces of the glass epoxy substrate 11 after the lands 13 and the Cu wirings 14 are formed, and the surface of the solder mask 15
15 is made rough thereafter in the aforementioned embodiment, the solder resist 15 may be replaced with other material so long as it can seal the lands 13 and the Cu wirings 14 airtightly and the surface thereof can be made rough easily.

20 Although the chip-mounting substrate of a single layer is used in the aforementioned embodiment, the chip-mounting substrate of multi-layers may be adopted. Moreover, two or more semiconductor chips 20 may be stacked on the chip-mounting substrate 10.

25 Moreover, although the CSP is adopted in the aforementioned embodiment, a BGA package or a FC package may be adopted in the other embodiment.

Although the chip-mounting substrate 10 is grinded mechanically in the aforementioned embodiment, the chip-mounting substrate 10 may be grinded and made rough chemically by soft etching.

5 Although the chip-mounting substrate 10 is made rough in the aforementioned embodiment, the printed circuit board 30 may be made rough as shown in FIG.3A. Moreover, both the chip-mounting substrate 10 and the printed circuit board 30 may be made rough as shown in FIG.3B.

10 The surface of the chip-mounting substrate 10 or of the printed circuit board 30 may be shaped into a dimple-like configuration or into a slit-like configuration as shown in FIG.4A or in FIG.4B instead of making it rough simply.

15 [The Second Preferred Embodiment]

Next, the second preferred embodiment of the invention will be explained referring to the appended drawings.

20 A semiconductor device according to the second preferred embodiment is the same as the semiconductor device according to the first preferred embodiment substantially, and provided with a chip-mounting substrate 40, a semiconductor chip 50, and a printed circuit board 60 as shown in FIG.5D. However, unevenness is not formed on a surface of the chip-mounting substrate 40 situated opposite to the printed circuit board 60, but on contact surfaces between Cu wirings 45 and solder balls 53.

Next, a method for fabricating the semiconductor device according to the second preferred embodiment will be explained.

First, as shown in FIG.5A, through holes 42 are formed on a periphery of a glass epoxy substrate 41 by means of photolithography or a laser beam irradiation, and subsequently, a Cu layer 43 is formed on both the surfaces of the glass epoxy substrate 41 including inner surfaces of the through holes 42. Next, a surface of the Cu layer 43 formed on a bottom surface of the glass epoxy substrate 41 (a surface on which Cu wiring layers 45 are to be formed) is grinded mechanically by means of a buff brush, and made rough. Thereafter, the surface of the Cu layer 43 which has been made rough is washed by cleansing liquid.

Next, as shown in FIG.5B, the Cu layer 43 is etched. Then, lands 44 are formed on a top surface of the glass epoxy substrate 41 (a surface on which the Cu layer 43 is not made rough), and the Cu wirings 45 are formed on the bottom surface of the glass epoxy substrate 41 (the surface on which the Cu layer 43 has been made rough). Subsequently, a solder mask 46 is formed on both the surfaces of the glass epoxy substrate 41. Then, the solder mask 46 formed on the lands 44 and the Cu wirings 45 is etched to form the contact holes 47 communicating with the Cu wirings 45. By the aforementioned process, the Cu wirings 45 are exposed, where the surfaces of the Cu wirings 45 have been made rough.

Next, as shown in FIG.5C, the semiconductor chip 50 adheres to a central area of the glass epoxy substrate 41 by means of die bonding material 48. Subsequently, pads formed on the semiconductor chip 50 are connected with the lands 44 by Au wires 51, and the semiconductor chip 50, the Au wires 51,

and the lands 44 are sealed with resin 52. Thereafter, solder balls 53 are connected with the Cu wirings 45 by thermal compression welding, where the surfaces of the Cu wirings 45 have been made rough beforehand.

5 Next, as shown in FIG.5D, in order to assemble the chip-mounting substrate 40 on which the semiconductor chip 50 has been mounted into the printed circuit board 60, the solder balls 53 connected with the chip-mounting substrate 40 are aligned with the corresponding pads 61 formed on the printed
10 circuit board 60, and they are brought into contact with each other.

Finally, underfill material 62 is injected into a clearance formed between the chip-mounting substrate 40 and the printed circuit board 60, and hardened.

15 As mentioned in the above, since areas of jointed surfaces between the Cu wirings (the pads) 45 and the solder balls 53 increase because of unevennesses provided for the surfaces of the Cu wirings (the pads) 45, the adhesive strengths between the Cu wirings 45 and the solder balls 53 are heightened. As
20 a result, the joined surfaces between the pads 45 and the solder balls 53 are prevented from being cracked by impacts caused by fallings, bendings, or thermal shocks. Accordingly, the semiconductor device operating in the electronic circuit with high reliability can be provided.

25 Although the surface of the Cu layer 43 has been made rough before the Cu wirings 45 are formed in the aforementioned embodiment, a following method may be adopted. That is to say, the solder mask 46 is formed on the Cu wirings 45, the solder

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mask 46 is etched to expose the surfaces of the Cu wirings 45, and the surfaces of the Cu wirings 45 are made rough thereafter.

Although unevennesses are provided for the pads 45 formed on the chip-mounting substrate 40 in the aforementioned embodiment, unevennesses may be provided for the pads 61 formed on the printed circuit board 60 as shown in FIG. 6A. Moreover, as shown in FIG. 6B, unevennesses may be provided for the pads 45, 61 respectively formed on the chip-mounting substrate 40 and the printed circuit board 60.

[The Third Preferred Embodiment]

Next, the third preferred embodiment of the invention will be explained referring to the appended drawings.

As shown in FIG. 9B, a semiconductor device according to the third preferred embodiment is provided with a lead frame 70, a semiconductor chip 80, and a printed circuit board 90.

The lead frame 70 is provided with inner leads 71 and outer leads 72, and the semiconductor chip 80 adheres to a central area of the lead frame 70 by means of die bonding material 73.

A part of the inner lead 71 is plated with Au (not shown), and the Au-plated parts of the inner leads 71 are connected with pads 81 formed on the semiconductor chip 80 by Au wires (bonding wires) 83. The outer leads 72 are connected with pads 91 formed on a printed circuit board 90. Unevenness is formed on a contact surface between the pad 91 and the outer lead 72.

Next, a method for fabricating the semiconductor device according to the third preferred embodiment will be explained.

First, two parts of a bottom surface of the lead frame

70 on which the outer leads 72 are to be formed are grinded by a buff brush, and made rough. Thereby unevennesses are formed on the two predetermined parts of the lead frame 70 as shown in FIG.7B. Subsequently, the lead frame 70 is so processed by using a metal mold that the inner leads 71 and the outer leads 72 are formed as shown in FIG.7A. Thereafter, portions of the inner leads 71 which are to be electrically connected with the semiconductor chip 80 are plated with Au.

Next, as shown in FIG.8, the semiconductor chip 80 adheres to the central area of the lead frame 70 by means of die bonding material 73, and the pads 81 formed on the semiconductor chip 80 are connected with the inner leads 71 by the Au wires 83. Thereafter, the semiconductor chip 80 and the Au wires 83 are sealed with sealing resin 82.

Next, as shown in FIG.9B, unnecessary parts of the lead frame 70 are punched by the metal mold, and predetermined portions of the outer leads are bent.

Finally, as shown in FIG.9B, in order to assemble the lead frame 70 on which the semiconductor chip has been mounted into the printed circuit board 90, the position of the lead frame 70 relative to the printed circuit board 90 is adjusted, and the outer leads 72 are connected with the pads 91 formed on the printed circuit board 90 by thermal compression welding.

As mentioned in the above, since areas of the contact surfaces between the outer leads 72 and the printed circuit board 90 are increased by providing unevennesses for the surfaces of the outer leads 72, adhesive strength between the lead frame 70 and the printed circuit board 90 are heightened.

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